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Research education

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Introduction

How can we get the public to appreciate the way scientific understanding advances via iterative research? How can we provide females and underrepresented minorities an opportunity to be involved in science early enough in their schooling to make a difference in career motivation? How can research laboratories help improve science education in our schools and prepare students with skills that they will need in the workforce? We do not have the answers to these questions. Indeed, we are only beginning to work together, as researchers and educators, on these topics. However, the Editor, upon seeing the large number of student and educator coauthors on our paper in this issue of *Journal of Geophysical Research*, invited us to describe our fledgling program, with the hope of stimulating dialogue on a topic of increasing interest.

Philosophy and Team Approach

Our assumption is that people can understand the nature of research best by becoming involved in research. Our philosophy is that students and educators should work with scientists on problems at the top of their research agenda. This helps assure that the activity has the researchers' highest priority, and also the perceived significance helps capture the interest of the students and educators. Our procedure is to provide the students and faculty roles in research projects at the NASA Goddard Institute for Space Studies (GISS), with the responsibility to produce both research results and educational materials that allow them to share the research experience with their peers.

Practical considerations require that the students, educators, and researchers be divided into teams focused on specific research tasks. Our approach is to have each research team or subteam group include student(s), educator(s), and GISS scientist(s). Research topics of the different teams are related so that communication among the teams provides participants a broader perspective of the research field. In this note we briefly discuss the overall education outreach program at GISS, but we focus on the specific team involved in the research paper published in this issue of the journal.

Institute on Climate and Planets

In 1994, GISS and the City University of New York (CUNY) initiated a cooperative agreement to establish an Institute on Climate and Planets (ICP), thus allowing students and educators of CUNY colleges and New York City schools to work with GISS scientists on NASA research projects. NASA supports full-time participation of students and educators at GISS during the summer. Participants continue to work with their research teams on a part-time basis during the academic year, with most college students receiving scholarship support from the National Science Foundation (NSF) Alliance for Minority Participation (AMP) program.

The CUNY schools range from 2-year community colleges to 4-year colleges. The high schools include neighborhood schools and specialized science high schools with competitive admissions. Recently, a junior high school has been added to our program.

The ICP has simultaneous objectives in science education, research, and minority participation. Our original concept for achieving these objectives [*Hansen et al.*, 1990, 1993] was to involve New York City schools in obtaining and analyzing small satellite observations of the Earth's climate, somewhat analogous to successful programs in space science observations at the Universities of Iowa and Colorado but carried out in an urban area and involving younger students with the aim of increasing the flow of underrepresented minorities into science or technical career pathways. In the absence of the proposed small satellite observations activity the most promising training tool that we have at GISS is our global climate modeling. Thus we are centering our education outreach program around global climate modeling but also including activities using satellite data, Sun photometers, and polarimeters, for example.

"Pinatubo" Team Research

The objective of the "Pinatubo" team is to study the climate effect of all measured radiative forcings in the period of satellite data (especially aerosols from the 1991 eruption of Mount Pinatubo) and to contrast this with unforced climate variability ("chaos"). In the first summer of the ICP program the students on the Pinatubo team were each assigned a climate parameter (surface, tropospheric, or stratospheric temperatures, precipitation, winds, or planetary radiation balance) and were asked to examine how well the current version of the GISS global climate model simulated observed climatology. Results of these initial tests were published by *Hansen et al.* [1996].

In its second summer the Pinatubo team initiated a set of simulations with a frozen version (S195) of the global climate model (GCM), adding radiative forcings to the model one by one and using several representations for the ocean. Fluxes delivered by the S195 model to the ocean were less realistic than desired, but we decided to carry out a full set of experiments anyhow to reveal more fully the difficulties of experiment implementation. The experiments were "successful" in this regard, as we learned that our procedure for implementing the standard Bryan-Cox ocean model was flawed and also that we had inadvertently added a radiative forcing in our transient experiments which forced us to subtract control runs with the same inadvertent forcing. Nevertheless, this first set of experiments yielded significant conclusions [see *Hansen et al.*, this

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issue]. We plan to run a cleaner set of these experiments with an improved version of the model (S197).

Pinatubo students in the past two years have become involved in individual projects, with the advice of a GISS scientist and an educator. Their topics include testing of proposed climate model improvements, preparation of soil moisture initial conditions for seasonal predictability experiments, examination of observations and model results for changes in precipitation intensities, and comparison of the model with observed features of the North Atlantic oscillation. Three of the students have been semifinalists in the Westinghouse Science competition for their research projects. The students have described their research in various forums, mainly to their peers, but also including a joint seminar at the Geophysical Fluid Dynamics Laboratory.

The ICP student-educator-researcher teams, in addition to "Pinatubo," now include research teams abbreviated as "oceans," "aerosols," "clouds," "polarimetry," "methane," and "climate impacts," some of these having been spun off from Pinatubo. The interrelationships among these projects help the students learn from each other and gain a broader perspective of the field.

Classroom Relevance

The educators are using their ICP experience in regular science classes and in special research classes at their home institutions. The intent is that all of their students should develop some understanding of inquiry-based iterative science research methods. Thus activities have been developed using NASA data to illustrate fundamental science concepts, and the research experiences of the students and teachers at GISS are shared with all students.

Each of the participating schools and colleges is establishing a research class, allowing a large number of students to participate in activities that expand upon the projects of the students and educators who work on-site at GISS. The research classes include the use of personal computers with Internet access to satellite and other data, model simulations, and research tools at GISS. The students in these classes not only develop some appreciation for the research process but also obtain practical experience in the use of personal computers, operating systems, and software for the manipulation and display of data.

A present focus of the ICP teams is to develop research-based activities that can be used as curriculum modules implemented on personal computers. Our intent is to organize these activities as a "virtual" research "institute" that can be visited via the Internet, allowing participation and contribution to ICP research teams. Within this "institute" users will have the opportunity to access real data and model results, analyze and interpret data, and formulate interpretations and questions. It is hoped that such a research and education tool can make a contribution to science education.

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